SPECIFICATION

RANGE FINDER DEVICE AND CAMERA

Technical Field

The present invention relates to a range finder device for measuring a three-dimensional shape of an object.

Background Art

As a range finder device for performing three-dimensional shape measurement based on triangulation of projected light and an observed image, such a real-time operable range finder device as shown in, for example, FIG. 40 has been proposed.

In FIG. 40, reference numerals 101A and 101B denote laser light sources having slightly different wavelength; 102, a half mirror for synthesizing laser light from the laser light sources having the different wavelength; 103, a light source control part for controlling light intensity of the laser light source; 104, a rotary mirror for scanning laser light; 105, a rotation control part for controlling the rotary mirror; 106, an object; 107, a lens for forming an image on CCD; 108A and 108B, light wavelength separation filters for separating light having wavelength from the laser light source; 109A and 109B, CCD for picking up a monochromatic image; 109C, CCD for picking up a color image;

110A and 110B, signal processing parts for a monochromatic camera; 111, a signal processing part for a color camera; 112, a distance calculation part for calculating a distance or a shape of an object from intensity of laser light photographed by CCD 109A and 109B; and 113, a control part for adjusting synchronization of the entire device. Hereinafter, the description will be made of the operation of a range finder device thus configured.

The laser light sources 101A and 101B emit laser light having slightly different wavelength. This laser light is line light having a light cross-section perpendicular to the scanning direction of a rotary mirror to be described later, and becomes line light in the perpendicular direction when a rotary mirror scans in the horizontal direction.

FIG. 41 shows wavelength characteristics for these two light sources. The reason why use of two light sources having close wavelength to each other are used resides in the fact that it is caused to be less influenced by dependency of the reflection factor of the object on wavelength. The laser light emitted from the laser light sources 101A and 101B is synthesized by the half mirror 102, and is scanned on the object 6 by the rotary mirror 104.

This scanning of the laser light is performed when the rotation control part 105 drives the rotary mirror 104 at one field period. At that time, light intensities of both light sources is varied as shown in FIG. 42(a) within one field period. The variations in the laser light intensity are synchronized with driving of the mirror angle, whereby the intensities of those two laser light are monitored by CCD 109A and 109B to calculate the light intensity ratio, making it possible to measure a time at one scanning period. If the light intensity is Ia/Ib as shown in, for example, FIG. 42(b), the scanning time is measured to be t0, and a rotation angle (ϕ) of the rotary mirror 104 can be known from the measured value.

The ratio of the intensities of those two laser light and the mirror angle (that is, angle of the object as viewed from the light source side) are caused to have a one-to-one correspondence therebetween in this manner, whereby the distance or shape of the object can be calculated from a ratio of signal levels on which light from both light sources has been photographed in a distance calculation part to be described later in accordance with the principle of triangulation.

The lens 7 [sic] forms an image of the object on CCD 109A, 109B and 109C. The light wavelength separation filter 108A transmits light in wavelength of the light

source 101A, and reflects light in other wavelength. The light wavelength separation filter 108B transmits light in wavelength of the light source 101B, and reflects light in other wavelength. As a result, reflected light of light of the light sources 101A and 101B from the object is photographed by the CCD 109A and 109B, and light of other wavelength is photographed by the CCD 109C as a color image.

The light source A signal processing part 110A and light source B signal processing part 110B perform the similar signal processing to an ordinary monochromatic camera for output from the CCD 109A and 109B. The color camera signal processing part 111 performs an ordinary color camera signal processing for output from the CCD 109C.

The distance calculation part 112 calculates a distance for each pixel from signal level ratio, base length and coordinate values of pixels which have been photographed by the CCD 109A and 109B for wavelength of each light source.

FIGS. 43(a) and (b) are explanatory views for graphically illustrating the distance calculation. In the figures, the reference character O denotes a center of the lens 107; P, a point on the object; and Q, a position of an axis of rotation of the rotary mirror. Also, for brevity, the position of the CCD 109 is shown turned around

on the object side. Also, assuming the length of OQ (base length) to be L, an angle of P as viewed from Q in the XZ plane to be ϕ, an angle of P as viewed from O to be θ, and an angle of P as viewed from O in the YZ plane to be ω, the three-dimensional coordinate of P can be calculated by the following formula (1) from the graphical relation.

$$Z = D \tan\theta \tan\phi / (\tan\theta + \tan\phi) \quad \ldots\ldots \quad (1)$$

$$X = Z / \tan\theta$$

$$Y = Z / \tan\omega$$

The ϕ in the formula (1) is calculated by the light intensity ratio of laser light sources 101A and 101B monitored by the CCD 109A and 109B as described above, and θ and ω are calculated from coordinate values of pixels. Of the values shown in the formula (1), if all of them are calculated, the shape will be determined and if only Z is determined, the distance image will be determined.

On the other hand, for photography for a place where light from the light source cannot be directly irradiated onto an object, there has been known a camera using an optical fiber. For example, as one of endoscopes to be used at the time of examining the interior of human body, there are a gastrocamera and the like. In the case of the gastrocamera, the inner walls of the stomach is normally irradiated by light irradiation from the optical fiber,

reflected light from the inner wall portion is received by another optical fiber to be guided to an external camera part, and this is two-dimensionally processed to display the normal image on a monitor.

As a conventional object extraction method, the technique called "Chroma key" used in broadcasting stations is generally used.

This method is to arrange an object in front of a studio set configured by the background of a single color (blue) for photographing, and to judge that the blue portion is the background regarding any portions other than it as an attention object.

In such a conventional configuration as described above, however, a modulatable light source and light source sweeping means are indispensable, and there was a problem that since mechanical operations are included, the reliability of the device is low and the device is expensive.

Also, although the laser element is normally modulated for use, the output and wavelength of the laser element vary depending upon the temperature, and therefore, there is a problem that it is difficult to realize stable measurement.

Also, as in case of the conventional endoscope or the like, for photography for a place where light from the

light source cannot be directly irradiated onto an object, there was the problem that it is difficult to examine whether or not there is any projecting region because the image is of two-dimensional data in a camera using the optical fiber.

Disclosure of the Invention

The present invention has been achieved in the light of such problems, and is aimed to provide a stable range finder device free from any mechanical operations at low cost.

It is another object of the present invention to provide a range finder capable of measuring a distance of an object in a place where light from a light source cannot be directly irradiated onto the object.

It is further another object of the present invention to provide a camera which is simple in configuration and compact in size.

That is, the present invention is a range finder device, for measuring, when a plurality of projected lights having radiation patterns whose light intensity differs three-dimensional space-wise are irradiated onto an object from a light source on a time-sharing basis to image-pick up reflected light of said projected light from said object

with a camera, a distance using the light intensity of an image picked up,

characterized in that, with respect to each of a plurality of surfaces including the center of said light source and the center of a lens, there is obtained, in advance, relation between an angle of each projected light from said light source and light intensity in each surface,

characterized in that, at the time of actual distance measurement, light intensity of each pixel of said camera is measured, and on the basis of the light intensity thus measured, and relation between said angle and said light intensity on a predetermined surface corresponding to a coordinate position of said pixel measured, there is obtained said angle corresponding to said light intensity of the predetermined pixel thus measured, and

characterized in that, on the basis of these light intensity measured, said angles obtained and further two-dimensional coordinate position information on said predetermined pixel on the image, a distance to said object is calculated.

Further, the present invention is a range finder device, characterized by comprising:

a light source;

a first optical fiber for guiding light to be emitted from said light source;

light distribution means for dividing light guided by said first optical fiber into a plurality of courses;

a plurality of second optical fibers whose one end is connected to said light distribution means, for irradiating said light divided from an aperture at the other end thereof onto said object;

image pickup means for receiving reflected light of said irradiated light to acquire image data of said object; and

distance calculation means for calculating a distance to said object on the basis of said image data,

characterized in that intensity of light to be irradiated onto said object from said other end of each of said plurality of second optical fibers has distribution which is different on place.

Further, the present invention is a camera for shape measuring or object extracting, having light-emitting means for irradiating an object with projected light having a specified radiation pattern, for picking up reflected light of said light-emitting means from said object to obtain a depth image using light intensity of the image picked up, characterized in that said camera has such a structure that a distance between said light-emitting means and an image-pickup lens is variable, and characterized in that the interval between said

light-emitting means and said image-pickup lens can be taken sufficiently large during the use.

Brief Description of the Drawings

FIG. 1 is a block diagram showing the configuration of a range finder device according to a first embodiment of the present invention;

FIG. 2(a) is a perspective view showing the configuration of a light source in the range finder device according to the first embodiment, and FIG. 2(b) is a plan view showing the configuration of a light source in the range finder device according to the first embodiment;

FIG. 3 is a view showing a light pattern of a light source according to the first embodiment;

FIG. 4 is a view showing a light pattern of a light source according to the first embodiment and a light pattern in the case of emitting a plurality of lights;

FIG. 5 is a view showing relation between a light intensity ratio according to the first embodiment and an angle ϕ from a light source;

FIG. 6 is a calculation conceptual view showing three-dimensional positions X, Y and Z in the first embodiment;

FIG. 7 is a block diagram showing the configuration of a range finder device according to a second embodiment of the present invention;

FIG. 8 is a block diagram showing distance calculation and light intensity conversion according to the second embodiment;

FIG. 9 is a view showing a change in X-coordinate of light intensity in the second embodiment;

FIG. 10(a) is a block diagram showing the configuration of a range finder device according to a third embodiment of the present invention, and FIG. 10(b) is a block diagram showing the configuration of a modification of a range finder device according to the third embodiment of the present invention;

FIGS. 11(a) to (c) are explanatory views illustrating arrangement of a lens system according to the third embodiment, and FIG. 11(d) is an explanatory view illustrating arrangement of a transmittance change filter according to the embodiment;

FIG. 12(a) is an explanatory view illustrating the transmittance change filter according to the third embodiment, and FIG. 12(b) is an explanatory view illustrating distribution of light intensity based on the transmittance change filter according to the embodiment;

FIGS. 13(a) and(b) are outside drawings showing cameras for shape measurement and object extraction according to a fourth embodiment of the present invention;

FIG. 14 is a block diagram showing the configuration of a light source part of a camera according to the fourth embodiment of the present invention;

FIG. 15 is a view showing the principle of a light source part of a camera according to the fourth embodiment of the present invention;

FIG. 16 is a view showing the light intensity of a light source part of a camera according to the fourth embodiment of the present invention;

FIG. 17 is a view showing a light intensity pattern of a light source part of a camera according to the fourth embodiment of the present invention;

FIG. 18 is a view showing a light intensity pattern of a light source part of a camera according to the fourth embodiment of the present invention;

FIG. 19 is a view showing a light intensity ratio of a light source part of a camera according to the fourth embodiment of the present invention;

FIGS. 20(a) and (b) are block diagrams showing a camera according to the fourth embodiment of the present invention;

FIGS. 21(a) to (d) are block diagrams showing a camera (2) according to the fourth embodiment of the present invention;

FIGS. 22(a) and (b) are outside drawings showing a camera (3) according to the fourth embodiment of the present invention;

FIGS. 23(a) to (c) are block diagrams showing a camera (4) according to the fourth embodiment of the present invention;

FIGS. 24(a) to (d) are block diagrams showing a light source part of the camera (2) according to the fourth embodiment of the present invention;

FIG. 25 is a view showing a display method (1) of a camera according to a fifth embodiment of the present invention;

FIG. 26 is a view showing a display method (2) of a camera according to the fifth embodiment of the present invention;

FIG. 27 is a rear outside drawing showing a camera according to the fifth embodiment of the present invention;

FIG. 28 is a block diagram showing a camera according to the fifth embodiment of the present invention;

FIG. 29 is a view showing an image correcting operation (1) of a camera according to the fifth embodiment of the present invention;

FIG. 30 is a view showing an image correcting operation (2) of a camera according to the fifth embodiment of the present invention;

FIG. 31 is another block diagram showing a camera according to the fourth embodiment of the present invention;

FIG. 32 is a view showing occurrence of occlusion in cameras according to the fourth and fifth embodiments of the present invention;

FIG. 33 is a view showing occlusion in cameras according to the fourth and fifth embodiments of the present invention;

FIG. 34 is a view showing a method of avoiding occlusion in cameras according to the fourth and fifth embodiments of the present invention;

FIGS. 35(a) and (b) are outside drawings for avoiding occlusion in a camera (1) according to the fourth and fifth embodiments of the present invention;

FIGS. 36(a) and (b) are outside drawings for avoiding occlusion in a camera (2) according to the fourth and fifth embodiments of the present invention;

FIGS. 37(a) and (b) are outside drawings for showing an external light source part (1) in a camera according to the fourth and fifth embodiments of the present invention;

FIGS. 38(a) and (b) are outside drawings for showing an external light source part (2) in a camera according to the fourth and fifth embodiments of the present invention;

FIGS. 39(a) and (b) are outside drawings for showing an external light source part (3) in a camera according to the fourth and fifth embodiments of the present invention;

FIG. 40 is a block diagram showing a conventional range finder device;

FIG. 41 is a characteristic diagram showing wavelength characteristic of a light source for a conventional range finder device;

FIGS. 42(a) and (b) are characteristic diagrams showing intensity modulation in a light source for a conventional range finder device; and

FIGS. 43(a) and (b) are views showing the principle of measurement in a range finder.

(Description of the Symbols)

1 Camera

1a Infrared camera

2a Light source

2b Light source

3a Infrared transmission filter

3b Infrared transmission filter

4a ND filter whose transmittance varies in the horizontal direction

4b ND filter whose transmittance varies in the horizontal direction

5 Light source control part

6 Distance calculation part

7 Flash light source

8 Flash light source

9 Passive reflection plate

10 Passive reflection plate

11a Field memory a

11b Field memory b

12a Light intensity conversion part a

12b Light intensity conversion part b

13 Light intensity ratio calculation part

14 Distance conversion part

101A Laser light source

101B Laser light source

102 Half mirror

103 Light source control part

104 Rotary mirror

105 Rotation control part

106 Object

107 Lens

108A Light wavelength separation filter

108B Light wavelength separation filter

109A Image pickup element

109B Image pickup element

109C Color image pickup element

110A Camera signal processing part

110B Camera signal processing part

111 Color camera signal processing part

112 Distance calculation part

113 Control part

201 Semiconductor laser

202 First optical fiber

203 Light distributor

204 Collimator lens

206 Camera part

207 Second optical fiber

501 Housing

502 Housing503 Lens

504 Recording media

505 First strobe

506 Second strobe

507 Finder

508 Strobe part

509 Camera body housing

510 Joint part

511 Camera body

512 Light source part housing

513 Light source part housing

514 Third strobe

515 Fourth strobe

516 Joint part

517 Light source part

518 Display panel

519 Touch panel

520 Object (foreground)

521 Object (background)

527 Portion judged to be the foreground by malfunction

528 Shading plate

529 Strobe light-emitting tube A

530 Strobe light-emitting tube B

531 Liquid crystal barrier

532 Display part

533 Image pickup part

534 Light control part

535 Distance calculation part

536 Color image calculation part

537 Control part

538 Media recording and reproducing part

539 Analysis part

540 Object (foreground)

541 Object (background)

542 Portion for which light from the light source part is intercepted

543 Light source part 3

544 Light source part 4

545 Camera mounting screws

546 Light source part housing (1)

547 Light source part housing (2)

548 Light source part fixing base

549 Light source part fixture (strobe shoe fitting)

550 Image memory

551 Passive reflection plate (1)

552 Passive reflection plate (2)

5100 Portion which has been judged to be the background

Best Mode for Carrying Out the Invention

Hereinafter, with reference to the drawings, the description will be made of a range finder device according to embodiments of to the present invention.

(First Embodiment)

FIG. 1 is a block diagram showing a range finder according to a first embodiment of the present invention. In FIG. 1, the reference numeral 1 denotes a camera; 2a and 2b, light sources; 5, a light source control part; and 6, a distance calculation part. Hereinafter, the

description will be made of an operation of the above-described configuration.

The light source control part 5 causes the light sources 2a and 2b to alternately emit light for each field period in synchronism with a vertical synchronizing signal of the camera 1. As the light sources 2a and 2b, there can be used those in which flash light sources 7 and 8 such as xenon flash lamps are lengthwise arranged and the directions of passive reflection plates behind them are laterally deviated as shown in, for example, FIG. 2(a). FIG. 2(b) is a plan view of FIG. 2(a). The light sources 2a and 2b radiate light within ranges A and B respectively. This xenon lamp has a small-sized light emitting portion, and one which can be regarded as a point light source as viewed from above is preferable. Further, the light sources 2a and 27b [sic] are lengthwise arranged, the distance therebetween is about 1 cm, and these light sources look as if light was emitted substantially from one point.

A light pattern to be radiated from such light sources becomes as shown in FIG. 3. This indicates, when light is projected onto a provisional screen, a size of brightness of the screen surface by a direction -> in the figure. That is, the respective light sources have characteristic properties that the screen surface is brightest at the central axis, and becomes darker toward the marginal

portion. It is bright at the center and dark in the marginal portion in this manner because semi-cylindrical passive reflection plates 9 and 10 are located behind the flash light sources 7 and 8. Also, the directions of those semi-cylindrical passive reflection plates 9 and 10 are deviated, and the respective projected light is emitted so that it is partly overlapped.

FIG. 4 shows relation between angles of projected light from the light sources and light intensity in a plane of H direction of FIG. 3. This H direction is a direction of a crossing line between an arbitrary plane S, of a plurality of planes including the center of the light source and the lens center, and the above-described provisional screen. In α portion of these light patterns, light to be irradiated from two light sources into the object space becomes bright on the right side in one and bright on the left side in the other as viewed from each light source. This pattern varies, however, also in the height-wise direction (Y direction).

FIG. 5 indicates the relation between the light intensity ratio in the object illumination by the two projected lights and an angle ϕ, made by the X-axis, of the one obtained by projecting the projected light onto the XZ plane in the α portion in FIG. 4. In the α portion, the relation between the light intensity ratio and angle

ϕ is a one-to-one correspondence. In order to measure a distance, two types of light patterns are alternately projected onto a plane, which is spaced apart by a predetermined distance from the light sources and is set up vertically, and such data on the relation between light intensity ratio and angle of projected light as shown in FIG. 5 is obtained in advance for each Y-coordinate (which corresponds to Y-coordinate on CCD) from the result obtained by image-picking up this reflected light with the camera 1. The "for each Y-coordinate" means for each of a plurality of planes including the light source center and the lens center.

Also, if the light sources are located such that a segment between the lens center of the camera 1 and the light sources runs parallel to the X-axis of the CCD image pickup surface, distance calculation can be accurately performed through the use of data on the relation between the light intensity ratio determined for each Y-coordinate and the angle of projected light. Hereinafter, the description will be made of a distance calculation method using the light intensity ratio.

When a point P in FIG. 1 is set to an attention point, an angle ϕ of the point P as viewed from the light sources is measured through the use of a luminance ratio obtained from image pickup data when two types of light patterns

are irradiated concerning the point P in an image picked up by the camera 1, and the relation of FIG. 5 corresponding to a Y-coordinate value of the point P. In this respect, an assumption is made that the relation of FIG. 5 has the characteristic properties that vary depending upon the Y-coordinate value as described above, and that the relation between the light intensity ratio and an angle ϕ from the light sources in the horizontal direction has been prepared by preliminary measurement for each Y-coordinate. Also, an angle θ with respect to the point P as viewed from the camera is determined by the position (that is, pixel coordinate value of the point P) in the image, and a camera parameter (focal length, optical center position of the lens system). Thus, the distance is calculated from the two angles and a distance (base length) between the light source position and the optical center position of the camera in accordance with the principle of triangulation.

Assuming the optical center of the camera to be the origin, setting the optical axis direction of the camera as Z-axis, the horizontal direction as X-axis, and the perpendicular direction as Y-axis, and assuming an angle, made by the X-axis, of the direction of the attention point as viewed from the light source to be ϕ, an angle, made by th X-axis, of the direction of the attention point

as viewed from the camera to be θ, and the light source position to be (0, -D), that is, the base length to be D, the depth value Z of the attention point P can be calculated from the above-described formula (1)

$$Z = D \tan\theta \tan\phi / (\tan\theta - \tan\phi)$$

According to the present embodiment as described above, a distance is measured by correcting any variations in light intensity generated by light sources or the optical system at the time of measuring the distance by means of a range finder using light intensity, whereby it is possible to realize a stable range finder device with high precision capable of implementing all by electronic operations.

In this respect, at the front of an infrared camera having a range finder according to the present embodiment, a half mirror or a dichroic mirror and a color camera are arranged, whereby a color image having the same viewpoint as well as the distance image can be obtained, and this technique is included in the present invention.

In this respect, in the distance calculation part according to the present embodiment, the description has been made of the case where only the distance Z is calculated to output the calculation result as a distance image, but it may be possible to output three-dimensional coordinate data by calculating all three-dimensional coordinate values X, Y and Z from formulas (1) and (2) using an angle

ω shown in FIG. 6, and this technique is included in the present invention.

$$X = Z / \tan\theta$$

$$Y = Z / \tan\omega \quad ..... \quad (2)$$

In this respect, in the present embodiment, if light sources 2a and 2b are caused to emit light at the same time, and are used as a normal flash lamp in which brightness in one center is great and the marginal portion becomes dark as indicated by a dotted line in FIG. 4, a normal two-dimensional image can be image-picked up.

Also, in the present embodiment, if an infrared passing filter is inserted at the front of the light source 2 and a filter having sensitivity in an infrared wavelength area is used for the camera 1, it is made possible to prevent lighting of a flashlight from hindering the user or an image pickup picture by the user or the other camera. Also, if an image is image-picked up coaxially with the infrared camera and by an ordinary color camera using a half mirror, a dichroic mirror and the like, a depth image and a texture image corresponding thereto can also be image-picked up at the same time.

Also, in the present embodiment, since the flashlight flashes for hundreds microsecond, if the camera 1 is set so as to be exposed by means of a shutter operation only during such period, it will be possible to suppress the

background light from affecting the distance measurement and to image-picked up a distance image even in a place which is bright to some degree.

Also, in the present embodiment, two types of light patterns are irradiated onto an object, and the light intensity ratio for each pixel has been calculated using image pickup pictures in the respective cases. It may be possible, however, to also image-pick up an image when no light pattern is irradiated and obtain three types (two types of light patterns and one type of no light pattern) of images in total for calculation. In this case, at the time of calculating the light intensity ratio for each pixel, a differential value obtained by subtracting light intensity in the absence of any light pattern from the respective light intensity values during light pattern irradiation will be calculated. Then, a ratio of these differential values will be calculated to make it into the light intensity ratio. Thus, in the case of image pickup in a bright place, it is possible to suppress distance calculation error based on background light.

(Second Embodiment)

FIG. 7 is a block diagram showing a range finder device according to a first embodiment of the present invention. In FIG. 7, the reference numeral 1a denotes a camera having sensitivity in infrared light; 2a and 2b, light sources;

3a and 3b, infrared transmission filters; 4a and 4b, ND filters whose transmittance varies in the horizontal direction; 5, a light source control part; and 6, a distance calculation part. Hereinafter, the description will be made of an operation of the above-described configuration.

The light source control part 5 causes the light sources 2a and 2b to emit light for each field period in synchronism with a vertical synchronizing signal of the infrared camera 1a. As the light sources 2a and 2b, a light source such as a xenon lamp, which flashes, having a small-sized light emitting portion,(which can be regarded as a point light source), is preferable. Also, the light sources 2a and 2b are arranged in the vertical direction.

At the front of each light source, there are arranged infrared transmission filters 3a and 3b, and ND filters 4a and 4b. The transmittance of the ND filter 4a, 4b varies in the horizontal direction. FIG. 2 shows a relation between an angle from the light source in the horizontal direction and the transmittance of the ND filters 4a and 4b.

Because of these ND filters, light to be irradiated in object space from two light sources becomes bright on the right side in one and bright on the left side in the other as viewed from the light sources. As a result, light

which is bright on the right side or on the left side as described above is alternately projected onto the object for each field period.

FIG. 5 indicates a relation between the light intensity ratio of the two projected lights and an angle from the light sources in the horizontal direction. Hereinafter, the description will be made of a distance calculation method using the light intensity ratio.

When a point P in FIG. 7 is set to an attention point, an angle of the point P as viewed from the light source is measured from a luminance ratio between fields concerning the point P in an image image-picked up by the camera 1a through the use of the relation of FIG. 5. Also, an angle with respect to the point P as viewed from the camera is determined from the position (that is, pixel coordinate value of the point P) in the image, and a camera parameter (focal length, optical center position of the lens system). Thus, the distance is calculated from the two angles and a distance (base length) between the light source position and the optical center position of the camera in accordance with the principle of triangulation.

Assuming the optical center of the camera to be the origin, setting the optical axis direction of the camera as Z-axis, the horizontal direction as X-axis and the vertical direction as Y-axis, and assuming an angle, made

by the X-axis, of the direction of the attention point as viewed from the light source to be ϕ, an angle, made by the X-axis, of the direction of the attention point as viewed from the camera to be θ, and the light source position to be (0, -D), that is, the base length to be D, the depth value Z of the attention point P can be calculated as the following formula:

$$Z = D \tan\theta \tan\phi / (\tan\theta - \tan\phi)$$

The distance calculation part 6 calculates a distance image from a video signal of the camera 1a. The calculation method may be the same as in the first embodiment, and there is another method capable of performing more accurate measurement as described below. FIG. 8 is a block diagram showing the distance calculation part 6. In FIG. 8, the reference numerals 711 [sic] and 11b denote field memories; 12a and 12b, light intensity correction means; 13, light intensity ratio calculation means; and 14, distance conversion means. Hereinafter, the description will be made of the operation of each component.

An image image-picked up by the camera 1a is written in the field memories 11a and 11b by each field.

The light intensity correction means 12a and 12b is means for correcting the light intensity written in the field memories. The reason for the correction will be described below. FIG. 9 shows a relation between the light

intensity to be image-picked up and the pixel coordinate value when light is irradiated (in a state free from any ND filter) on a screen having a fixed distance Z from a point light source to image-pick up light reflected by the surface. FIG. 9 one-dimensionally shows only in the horizontal direction for brevity, but the light intensity likewise shows curvilinear distribution also in the vertical direction.

As causes for this distribution, there are conceived peripheral extinction based on the lens system of the camera, variations in intensity of reflected light caused by variations in the angle of incidence of a ray of light with respect to the object surface, and variations in light intensity due to an angle from the light sources among others. Since the variations in light intensity caused by these causes become errors at the time of observing the light intensity ratio, that is, errors during distance measurement, it becomes necessary to convert the light intensity in order to improve the distance measurement accuracy. The presence of these errors may cause any portion other than a monotonous increasing curve in the characteristic curve of FIG. 5. In such a portion, the light intensity and the angle do not have a one-to-one correspondence therebetween, and as a result, the measurement result is disturbed. Also, if there were not

these errors, there would be advantages that the light intensity (ratio) in the Y-axis direction becomes constant, and that one conversion table of FIG. 5 is required (in the first embodiment, a conversion table for the number for Y-coordinate value is required).

In order to reduce the measurement errors in the light intensity conversion means 12a and 12b, two-dimensional curve distribution in light intensity in an image on a screen spaced apart by a reference distance in the absence of the ND filter is measured in advance, and at the time of obtaining relation (corresponding to FIG. 5) between the light intensity and the angle of the projected light, and at the time of measuring an actual distance of the object, the light intensity of the field memory is corrected and converted in accordance with the curve distribution in light intensity measured in advance. A factor (that is, ratio of light intensity picked up in each pixel corresponding to a peak value or an arbitrary value) for correcting the curve distribution of light intensity to a fixed value is held as a two-dimensional LUT (look-up table), and the correction and conversion are performed by multiplying the data in the field memory by a correction factor for each pixel.

The reference distance is, if a distance in arranging the object is known in advance, set to a value close to

the distance, to thereby make it possible to improve the accuracy at the time of measuring the distance.

According to the present embodiment as described above, a distance is measured by correcting any errors in light intensity caused by a light source or an optical system at the time of measuring the distance by means of a range finder using light intensity, whereby it is possible to realize a stable range finder device with high precision capable of implementing all by electronic operations.

In this respect, at the front of an infrared camera having a range finder according to the present embodiment, a half mirror or a dichroic mirror and a color camera are arranged, whereby a color image having the same point of view as well as the distance image can be obtained.

In this respect, in the distance calculation part according to the present embodiment, the description has been made of the example in which only the distance Z is calculated and the calculation result is outputted as the distance image, but it is possible to calculate all three-dimensional coordinate values X, Y and Z using the angle ω shown in FIG. 6 from the following formulas:

$$Z = D \tan \theta \tan \phi / (\tan \theta - \tan \phi)$$

$$X = Z / \tan \theta$$

$$Y = Z / \tan \omega$$

and to output the three-dimensional coordinate data.

In this respect, in the light intensity correction in the distance calculation part according to the present embodiment, in the case where the object is spaced apart from the reference distance, the position of pixels to be image-picked up is shifted (that is, a parallax occurs) and therefore, the distance measurement precision is deteriorated. In such a case, a plurality of light intensity correction amounts for reference distances are prepared in advance, correction for a certain reference distance is first performed to calculate the distance, and subsequently, the distance is calculated again by using a correction amount for a reference distance close to the previous case to thereby make it possible to improve the measurement precision.

In this respect, in the present embodiment, if light sources 2a and 2b are caused to emit light at the same time, and are used as a normal flash lamp in which brightness in one center is great and the marginal portion becomes dark as indicated by dotted line in FIG. 4, a normal two-dimensional image can be picked up.

Also, in the present embodiment, if an image is picked up coaxially with the infrared camera and by an ordinary color camera using a half mirror, a dichroic mirror and the like, a depth image and a texture image corresponding thereto can also be picked up at the same time.

Also, in the present embodiment, since the flashlight flashes for hundreds microsecond, if it is set such that the camera 1 is exposed by means of a shutter operation only during the period of time, it will be possible to suppress the background light from affecting the distance measurement and to pick up a distance image even in a place which is bright to some degree.

Also, in the present embodiment, two types of light patterns are irradiated onto an object, and the light intensity ratio for each pixel has been calculated using image pickup pictures in the respective cases. It may be possible, however, to also pick up an image when no light pattern is irradiated and to obtain three types (two types of light patterns and one type of no light pattern) of images in total for calculation.

In this case, at the time of calculating the light intensity ratio for each pixel, a differential value obtained by subtracting light intensity without light pattern from the respective light intensity values during light pattern irradiation will be calculated. Then, a ratio of these differential values will be calculated to make it into the light intensity ratio. Thus, in the case of image-picking up in a bright place, it is possible to suppress any distance calculation error based on background light.

Also, for the light pattern to be projected onto an object in the present embodiment, it may be possible to use a light transmission type liquid crystal display device (such device as used in an ordinary liquid crystal video projector) and one light source in place of the ND filters 4a and 4b whose transmittance varies in the horizontal direction and the light sources 2a and 2b. These ND filters and two light sources are switched to a light transmission pattern of the light transmission type liquid crystal display device to cause the light source to emit light twice, or the light source is left lighted to switch to two types of light patterns of the light transmission type liquid crystal display device, whereby it is possible to irradiate two types of light patterns onto the object on a time-sharing basis as in the case of the present embodiment.

(Third Embodiment)

FIG. 10(a) is a schematic perspective view showing a third embodiment of a range finder according to the present invention. With reference to the figure, the description will be made of the configuration of the present embodiment hereinafter.

As shown in FIG. 10(a), a semiconductor laser 201 is light source means for emitting light with a wavelength λ. A first optical fiber 202 is means for guiding light

to be emitted from the semiconductor laser 201 to a light distributor 203. Also, a collimator lens 204 is arranged between the first optical fiber 202 and the semiconductor laser 201. The light distributor 203 is light distribution means for dividing the light guided through the first optical fiber 202 into two courses. Also, the light distributor 203 has a shutter mechanism, and is means for transmitting the light divided to second optical fibers a and b on a time-sharing base. The second optical fiber a (205a) and the second optical fiber b (205b) are optical fibers connected, at one end thereof, to the light distributor 203 respectively, for irradiating the light divided from an aperture at the other end onto an object (for example, the inner walls of the stomach, or the like). A camera part 206 is image pickup means for acquiring image data of the object received through light-receiving optical fiber bundle 207 by means of reflected light from the object. In this respect, at the tip end of the light-receiving optical fiber bundle 207, there is arranged a lens 210 in proximity thereto. CCD 209 is an image pickup element mounted to the camera part 206 so as to receive light from the light-receiving optical fiber bundle 207. Light to be irradiated from the aperture 208a of the second optical fiber a (205a) shows such light intensity distribution as shown in FIG. 4 which has been

described in the embodiment. Light to be irradiated from the aperture 208b of the second optical fiber b (205b) is also the same. These lights has different light intensity distribution depending upon the position in the horizontal direction because light to be emitted from the aperture of the optical fiber diffuses based on the angular aperture. Therefore, by adjusting the angular aperture, the shape of the light intensity distribution can be changed. In this respect, this angular aperture can be adjusted to some degree by setting the refractive index of the optical fiber in the diameter-wise direction to a predetermined value.

In this respect, a range finder according to the present embodiment has distance calculation means (not shown) provided with the same function as the distance calculation part 6 described in the embodiment, for calculating a distance up to the object on the basis of image data from the camera part 206. Also, for both the first optical fiber 202 and the second optical fibers a and b (205a and 205b), or either of them, optical fiber bundle may be used as a matter of course.

With the above-described configuration, the operation of the present embodiment will be described with reference to FIG. 10(a).

A range finder according to the present embodiment can be utilized as an endoscope such as a gastrocamera.

More specifically, the tip ends of the second optical fibers a and b (205a and 205b) and the tip end of the light-receiving optical fiber 207 are inserted into the stomach of a patient.

From the apertures of the second optical fibers a and b, light having such light intensity distribution characteristic as shown in FIG. 4 is irradiated on the time-sharing basis as in the case of the first embodiment. The light-receiving optical fiber 207 receives light reflected by these light. Further, the camera part 206 transmits the image data on the inner walls of the stomach obtained from these light reflected to the distance calculation part. The distance calculation part calculates, as in the case of the first embodiment, the three-dimensional distance data on the inner walls of the stomach for outputting. The distance data outputted is transmitted to a monitor (not shown) to be three-dimensionally displayed. A doctor can, while viewing the monitor, view the image of the diseased portion which has three-dimensionally been displayed by moving the tip end of the second optical fiber. Thus, the doctor can more accurately examine than before.

In this respect, in the above-described embodiment, the description has been made of a range finder configured by one semiconductor laser as the light source part, but the present invention is not limited thereto, and a range finder configured by two light source parts as shown in, for example, FIG. 10(b) may be used. More specifically, in this case, semiconductor lasers 201a and 201b as the light source part are provided with optical fibers 205a and 205b for individually guiding those lights emitted on the object side to irradiate the object. Also, a collimator lens 204a, 204b is arranged between each optical fiber 205a, 205b and each semiconductor laser 201a, 201b. Such a configuration exhibits the same effect as described above.

Also, in the above-described embodiment, the description has been made of the configuration in which there is provided a light distributor 203 between the first optical fiber 202 and two second fibers 205a and 205b, but the present invention is not limited thereto, and it may be possible to construct, in place of, for example, the light distributor 203 and the second optical fibers 205a and 205b, such that light guided from the first optical fiber is divided into two courses at the tip end portion of the fiber and there is provided light branch means (not shown) for irradiating the object. In this case, the

second optical fiber can be omitted, and yet the same effect as described above is exhibited.

Also, in the above-described embodiment, the description has been made of the configuration in which nothing has been provided in front of the optical fibers 205a and 205b as shown in FIG. 11(a), but the present invention is not limited thereto, and it may be possible to construct such that a collimator lens 301 (See FIG. 11(b).) is arranged at the front of the aperture 208a, 208b of each optical fiber 205a, 205b, or that a cylindrical lens (or a rod lens) 302 (See FIG. 11(c).) is arranged at the front of each aperture 208a, 208b. This enables the intensity of light to be irradiated from the aperture to be position-wise uniformly varied more effectively. In this respect, it is also possible to output light, which has no different light intensity locally, from the front of each aperture 208a, 208b, and instead, to arrange a transmittance change filter 1 (303a) and a transmittance change filter 2 (303b), whose light transmittance differs position-wise, at the front of each aperture 208a, 208b.

With reference to FIGS. 12(a) and (b), the description will be further made of the characteristic properties of the filter shown in FIG. 11(d).

The intensity distribution of light, which passed through the transmittance change filter 1 (303a) shown

in, for example, FIG. 12(a), is set such that it becomes the one denoted by the reference numeral 401a in FIG. 12(b). In contrast, the intensity distribution of light, which passed through the transmittance change filter 2 (303b), is set such that it becomes the one denoted by the reference numeral 401b in the figure. FIG. 12(b) is a view representing the light intensity distribution for a range α shown in FIG. 4. The present invention can be implemented even if such transmittance change filter is used.

Also, in the above-described embodiment, the description has been made of the case where the light distributor has been provided with a shutter mechanism in such a manner that the object is irradiated with light on a time-sharing basis, but the present invention is not limited thereto, and for example, light from the light source includes light having a plurality of frequencies, and the light distributor is provided with a filter, whereby light having different wavelength is irradiated from the aperture. Thus, the camera part is provided with a filter and a light-receiving element, which are capable of distinguishing these two types of wavelength for receiving, to thereby make it possible to irradiate the object with each light having two types of wavelength at the same time. This enables the measuring time to be shortened. Even in the configuration shown in FIG. 10(b), if the wavelength

of the semiconductor lasers 201a and 201b are made different from each other, and the camera part 206 is provided with a filter and a light-receiving element, which are capable of distinguishing these two types of wavelength for receiving, it becomes possible to shorten the measurement time in the same manner as described above.

Also, in the above-described embodiment, a semiconductor laser has been used as the light source, but the present invention is not limited thereto, and for example, LED, a lamp or the like may be used.

Next, the description will be made of a camera according to the present invention, which is obtained by implementing such a contrivance as to make the above-described range finder device according to the present invention more compact and simple in configuration.

More specifically, in the above-described range finder device, the light passive reflection plates have been disposed in deviated relationship with each other with respect to the light sources 2a and 2b as shown in FIG. 2, it is necessary to mount light filters whose light transmittance differs depending upon the horizontal place in front of the light-emitting tube, and it can be said that the configuration is complicated.

Also, unless the camera lens and the light source are spaced more than several tens centimeters apart from each other, the measurement accuracy will not be possible because the triangulation is used, and the camera would be considerably large even if an attempt is made to house them within the camera housing.

Also, there was a defect that it is impossible to simply calculate to measure the sizes or dimensions of an object image-picked up with a conventionally-known camera unless the distance up to the object is known. Also, it was impossible to know the sizes of the object from a color image once picked up.

Also, when an attempt is made to extract an object from an image picked up with a conventionally-known camera, an environment having a background of a single color must be prepared in advance, and large-scale preparation was required.

Hereinafter, with reference to the drawings, the description will be made of a shape measuring camera and an object extracting camera capable of solving those inconveniences and the like, according to an embodiment of the present invention.

(Fourth Embodiment)

FIGS. 1(a) [sic] is a block diagram showing a shape measuring camera and an object extracting camera according

to a fourth embodiment of the present invention. Also, FIG. 20 is a block diagram showing this camera.

In FIG. 13, the reference numerals 501 and 502 denote a camera housing; 503, a photographing lens; 504, recording media; 505 and 506, first and second strobes, each forming the light source part respectively; and 507, a finder.

In FIG. 20, the reference numeral 532 denotes a display part; 533, an image pickup part; 534, a light source control part; 535, a distance calculation part; 536, a color image calculation part; 538, a media recording/reproducing part; and 550, an image memory.

This shape measuring camera is configured such that a housing 501 containing the camera part and a housing 502 containing a light-emitting part have different thickness from each other and can be fitted into each other in an overlapped manner as shown in FIG. 13(a), and further that the state of FIG. 13(a) or the state of FIG. 13(b) can be selected by sliding the housings 501 and 502 by the user. During carrying, the small-sized state is kept in the state of FIG. 13(a), while during image-picking up, the housing is extended into such a state as shown in FIG. 13(b) for use. This enables an interval D between the center of the lens 503 and the strobe 505, 506 in the light source part to be set large during the use. FIG. 20(a) shows a simple type using no image memory 550, and

FIG. 20(b) shows a type having an image memory, capable of image-picking up and displaying at high speed.

The strobe 505, 506 in the light source part is constructed as shown in, for example, FIG. 2, and is configured by a strobe light-emitting tube 530 and a shading plate 528 having a hole with the position of its center shifted. Light emitted from the segment of a light-emitting tube 530 is emitted while the way of intercepted light is varying depending upon the position by a shading plate 528 as shown in the plan view of FIG. 15. At this time, the position of the hole in the shading plate 528 is deviated from the strobe light-emitting tube 530, and such light as to become increasingly intenser from point A toward point B on a straight line 1 is generated. This generates such a light pattern that the light intensity varies in the opposite directions to each other from two strobe light-emitting tubes as shown in FIG. 16. Next, the description will be made of a method for calculating a depth distance using such light. In this respect, its contents are almost the same as the calculation method for depth distance already described.

A light pattern thus obtained is a pattern in which the light intensity varies as shown in FIG. 17. FIG. 18 one-dimensionally shows these variations in the light intensity in the horizontal X-direction. In α portion

of this light pattern, light to be irradiated from two light sources into the object space

becomes bright on the right side in one and bright on the left side in the other as viewed from each light source. This pattern varies, however, also in the height-wise direction (Y direction).

FIG. 19 shows the relation between the light intensity ratio and an angle ϕ from the light source in the horizontal direction in the object illumination by the above-described two projected light in the α portion of FIG. 18. In the α portion, the relation between the light intensity ratio and the angle ϕ from the light source in the horizontal direction is a one-to-one correspondence therebetween. In order to measure a distance, it is necessary to alternately project two types of light patterns onto a plane which has been set up vertically in advance, and to obtain in advance such data on the relation between light intensity ratio and position from the light source in the horizontal direction as shown in FIG. 17 for each Y-coordinate from the result obtained by image-picking up this reflected light with the camera 501.

Also, if the light sources are located such that a segment between the lens center of the camera 501 and the light source runs horizontal to the X-axis of the image

pickup surface, the distance can be accurately calculated through the use of data on the relation between a light intensity ratio determined for each Y-coordinate and positions from the light sources in the horizontal direction. This is calculated by the distance calculation part of FIG. 20(a). Hereinafter, the description will be made of a distance calculation method using the light intensity ratio.

In the case where a point P in FIG. 20(a) is set to an attention point, when two types of light patterns from respective strobes 505 and 506 in the light source concerning the point P on an image picked up by the image pickup part 533 on the basis of the user's image-picking up intention are projected by the light source control part 534 on a time-sharing basis, an angle ϕ of the point P as viewed from the light source is measured through the use of a luminance ratio obtained from the image pickup data, which is the output from the image pickup part 533, and the relation of FIG. 19 corresponding to the Y-coordinate value of the point P.

In this respect, the assumption is made that the relation of FIG. 19 has characteristic properties that differ depending upon the Y-coordinate value as described above, and that the relation between the light intensity ratio and the angle ϕ from the light source in the horizontal

direction has been prepared for each Y-coordinate by measurement in advance. Also, an angle θ with respect to the point P as viewed from the camera is determined from the position (that is, pixel coordinate value of point P) in the image, and a camera parameter (focal length, optical center position of lens system). Thus, the distance is calculated from the above-described two angles and the distance (base length D) between the light source position and the optical center position of the camera in accordance with the principle of triangulation.

Assuming the optical center of the camera to be the origin, setting the optical axis direction of the camera as Z-axis, the horizontal direction as X-axis, the vertical direction as Y-axis, and assuming an angle, made by the X-axis, of the direction of the attention point as viewed from the light source to be ϕ, an angle, made by the X-axis, of the direction of the attention point as viewed from the camera to be θ, and the light source position to be (0, -D), that is, the base length to be D, the depth value Z of the attention point P can be calculated as the following formula:

$$Z = D \tan\theta \tan\phi / (\tan\theta - \tan\phi)$$

When the value of D (distance between lens and light source part) is small at this time, accuracy of the depth value Z measured is degraded. If the D value is set to

20 to 30 cm for an object up to a distance of, for example, about 3 m, the depth can be measured with an error of plus or minus about 1% of the measured distance. As the D value becomes smaller than 20 to 30 cm, the measurement error further increases. Also, the X and Y coordinates of the attention point P are given by the following formulas:

$$X = Z / \tan \theta$$

$$Y = Z / \tan \omega$$

Also, a color image calculation part 536 calculates an image obtained by adding and averaging image pickup data when the above-described two types of light patterns are irradiated to make it into a color image. These two types of light patterns have characteristic properties that the brightness varies complementally to each other as shown in FIG. 18, and by adding and averaging them, the same color image as a color image obtained by picking up with strobes with uniform brightness can be obtained.

The color image and depth image which have been thus obtained are displayed on a display part 532, and are recorded in recording media 504 through a media recording/reproducing part 538. Of course, the color image and depth image which have been once recorded can also be read out by the media recording/reproducing part 538 to be displayed on the display part 532.

If the image data from the image pickup part 533 is once accumulated in an image memory 550 as shown in FIG. 20(b), the image can be continuously inputted. Also, a plurality of images recorded on the recording media 504 once also can be read out on the image memory 550 to be reproduced and displayed at high speed.

According to the present embodiment as described above, it is possible to generate a plurality of light patterns in a single configuration, and to realize a shape measuring camera with stable configuration only through the use of a straight-line shaped strobe light-emitting tube and a shading plate with a hole for a light intensity change pattern.

Also, it is possible to realize a shape measuring camera capable of taking the interval D large between the lens 503 and the strobes 505 and 506 in the light source part by making it small-sized during carrying and by extending the main body during image-picking up, and capable of measuring a depth image with high accuracy.

(Fifth Embodiment)

FIG. 28 is a block diagram showing a shape measuring camera and an object extracting camera according to a fifth embodiment of the present invention. In FIG. 28, the reference numerals 501 and 502 denote a camera housing; 505 and 506, first and second strobes, each forming the

light source part respectively; 518, a display panel; 519, a touch panel; 532, a display part; 533, an image pickup part; 535, a distance calculation part; 536, a color image calculation part; 538, a media recording/reproducing part; and 537, a control part. Hereinafter, the description will be made of the operation of the shape measuring camera and the object extracting camera having the above-described configuration.

FIG. 27 shows the back of the shape measuring camera. On the back, the display panel 518 and the touch panel 519 are piled up in a same position to display a color image or a depth image which has been picked up, and are configured such that the user can denote the attention position (coordinate) in the image using the finger or a rod-shaped object.

FIG. 28 is a block diagram showing display and distance measurement. A distance image and a color image which have been picked up are inputted into the control part 537, and user's attention position designating coordinates are also inputted into the control part 537. The control part 537 displays a color image picked up on the display panel 518 and calculates an actual distance and the like from a plurality of attention designating coordinates inputted by the touch panel 519 and a depth image to display on the display panel 518.

FIG. 25 shows an aspect of attention position designation. First, it is assumed that a color image for a desk picked up by the user is displayed on the display part 518. The user denotes designating points A523 and B524 using the finger or a rod-like object.

When they are denoted, the shape measuring camera calculates the distance Lab of a segment AB between points A and B, that is,

$$\mathrm{Lab} = \sqrt{\left\{(Xa - Xb)^2 + (Ya - Yb)^2 + (Za - Zb)^2\right\}}$$

using the values of actual coordinates A (Xa, Ya, Za) and B (Xb, Yb, Zb) of respective coordinate positions of the depth image obtained to display in another portion on the display panel 518. In this example, it is displayed that the length of AB is 25 cm. In this manner, the user can measure a distance between points, which should be measured, of the object image-picked up without touching it even if it is a length in the depth-wise direction.

Also, the size of a circular object and not a straight line-shaped object can be measured in the similar manner. FIG. 26 shows the case where a circular table has been image-picked up. For example, while viewing a color image which has been image-picked up and displayed on the display panel 518, the user denotes three points, A523, B524 and C526 of an adequate position of a circumferential portion

of a circle to be measured by touching them on the touch panel using the finger or a rod-shaped object.

Thereafter, the shape measuring camera determines, from space coordinate values A (Xa, Ya, Za), B (Xb, Yb, Zb) and C (Xc, Yc, Zc) for these three points, a formula for a circle which passes these points. Although there are various methods for determining it, for example, perpendicular bisectors for segments AB and BC are determined and their point of intersection is assumed to be the center G (Xg, Yg, Zg) of the circle. Next, a mean value of the length of segments GA, GB and GC can be made into the radius of the circle.

The radius thus obtained is displayed to be 50 cm in FIG. 26, of which the user is notified. By doing so, the size of such a complicated shape as a circle can also be measured without touching the object. In addition, for any shape having a mathematical expression for defining the shape such as an equilateral triangle and an ellipse, its size can be measured from the depth image without touching the object by designating a plurality of points by the user. Also, in this case, the user has inputted the coordinates for the attention point using the touch panel, but it may be possible to display a cursor (such as a figure of cross), which moves left, right, up or down, on the display panel 518, and to denote by moving its

position with a push-button for inputting the coordinates for the attention point.

If the size calculation result of the object is recorded in the recording media 504 through the media recording/reproducing part 538, it is not necessary for the user to keep the measurement result in mind, but the measurement result can be fetched from the recording media 504, and be conveniently used by equipment (such as a personal computer) having the same function as the media recording/reproducing part 538 capable of reading and writing the measurement result. Of course, the measurement result may be superimposed on the color image picked up to be preserved as an image.

In the foregoing example, the length of the object has been measured, and it is also possible to measure a plurality of length for determining the area or volume on the basis thereof.

Further, another example of display and utilization of the pickup data will be described.

As shown in FIG. 27, on the back of the camera, the display part 518 and the touch panel 519 are piled up in a same position to display a color image or a depth image which has been picked up, and are configured such that the user can denote the attention position (coordinate) in the image using the finger or a rod-shaped object.

Through the use of this, it is possible to realize an object extracting camera capable of obtaining an image obtained by extracting only an object, on which the user focuses attention.

FIG. 28 is a block diagram showing the display/extracting operation, and the object extracting camera has basically the same configuration as the above-described shape measuring camera. A distance image and a color image which have been picked up are inputted into the control part 537, and user's attention position designating coordinates are also inputted into the control part 537.

The control part 537 can display a color image picked up on the display panel 518 and extract only an object, at which the user aims, from a plurality of attention designating coordinates inputted by the touch panel 519 and a depth image to display on the display panel 518 for recording in the recording media 504.

With reference to FIG. 29, the description will be made of this operation.

First, the assumption is made that the user wishes to extract an object 520. The user denotes a portion of the object 520 on the touch panel 519. The control part 537 obtains the depth value of a portion including by this coordinate from the depth image, judges a portion having

a depth continuously connected therewith as an object, at which the user aims, for displaying only the portion, and fills any portions other than the portion with a certain specific color for displaying on the display panel 518.

As regards judgment as to such a connected portion, so-called image processing can be performed that with a denoted coordinate as a starting point, the area will be expanded left, right, up or down as far as the depth value continuously varies and if there is any discontinuous portion in depth, the expansion will be stopped there.

A little longer distance than a distance between an object which the user wishes to extract and the camera, or a range of such a distance that the user wishes to extract is denoted using the touch panel or the push-button. The control part 537 displays a portion of a color image having a closer value than a distance denoted by the value, or a color image included only in a portion within a range of the denoted distance, while the other portions are filled in with a certain specific color. Thus, they are displayed on the display panel 518, and are recorded in the recording media 504.

In this manner, the camera is capable of judging only the object, at which the user aims, for extracting to display and record it. In this case, there is a possibility that depending upon the image processing, there arises

a portion which is erroneously judged to be a foreground by a malfunction in spite of a background portion as shown in FIG. 30.

In this case, if the user denotes a portion (FIG. 29), in which the malfunction seems to have been done, by the touch panel 519 and corrects the display result so that the portion is the background, it will be possible to obtain a high-quality extracted color image for the object. In this case, of course, the user may denote the portion which has been erroneously judged to be the background by the malfunction to perform a correcting operation so that this portion becomes a foreground.

By extracting a color image according to the distance using the information on the depth image as described above, it is possible to easily obtain an image obtained by extracting only an object, at which the user aims, for preserving.

Also, in FIG. 28, an image memory is arranged within the control part 537, and an image to be reproduced and operated is once placed on the image memory, whereby it is also possible to make the access speed for images faster, or switch a plurality of images to high speed for displaying and operating.

According to the present embodiment as described above, it is also possible to measure an actual size of an object

without touching it. Also, it is possible to realize a shape measuring camera and an object extracting camera capable of easily extracting only an object, at which the user aims, on the basis of its depth information for preserving.

In the fourth embodiment, the similar effect can be obtained even if the housing for the shape measuring camera is constructed as shown in FIG. 21. More specifically, the configuration is arranged such that a camera part 9 [sic] containing an image pickup part 533 and a strobe part 508 containing first and second strobes 505 and 506 forming a light source are connected together by a joint 510 having a hinge-like configuration in such a manner that the user can freely fold as shown in FIG. 21(a) and extend as shown in FIG. 21(b). During carrying, the camera housing is small-sized in such a state as shown in FIG. 21(a), and during image-picking up, if it is extended as shown in FIG. 21(b) for use, the interval D between the lens 503 and the first and second strobes 505 and 506 in the light source can be made larger.

Also, the configuration can be arranged such that the lens and the first and second strobes 505 and 506 are vertically arranged as shown in FIG. 21(c). In this case, in the depth image calculation, while the angles ϕ and θ are changes in the horizontal direction in the foregoing,

the changes are only performed in the vertical direction, and the depth image can be calculated by the similar calculation for the others. In order to cause changes in the light intensity in the vertical direction, the light source is configured by vertically-laid light-emitting tubes as shown in FIG. 21(d).

In this case, even if the configuration is arranged such that a housing 501 containing such a camera part as shown in FIG. 21 and a housing 502 containing a light-emitting part have different thickness from each other and can be fitted into each other in a superimposed manner in a vertical direction as shown in FIG. 23, the similar effect can be obtained. At this time, the light source part is constructed as shown in FIG. 23(d) [sic].

In the fourth embodiment, the similar effect can be obtained even if the housing for a shape measuring camera is constructed as shown in FIG. 22. More specifically, the housing 517 containing the first and second strobes 505 and 506 in the light source part is made small-sized, and is connected to the camera housing 501 using the hinge configuration. During the use, the housing 517 is turned by the user to thereby expose the first and second strobes 505 and 506 in the light source part, whereby normally the housing can be made small-sized while the first and second strobes 505 and 506 in the light source part are

not exposed to thereby prevent them from being damaged due to any careless contact, and at the same time, during image-picking up, the interval D between these strobes and the lens can be made large.

In the fourth embodiment, although the light source is constructed as shown in FIG. 2, even if the configuration is arranged such that there is provided one light-emitting tube 529 and a liquid crystal barrier 531 is placed in front thereof as shown in FIG. 24(a), it is possible to have the similar light pattern generating function.

In this case, if it is arranged that each light transmittance portion is sequentially provided on the left side of the light-emitting tube 529 as shown in FIG. 24(b) and provided on the right-side thereof as shown in FIG. 24(c) in such a manner that the light-emitting tube 529 sequentially emits light once at a time in the respective states, then the same light pattern as shown in FIG. 18 can be generated by sequentially causing one light-emitting tube to emit light twice without using two light-emitting tubes as shown in FIG. 2.

This enables a small number of light-emitting tubes to emit light as if light were emitted from the same position instead of light-emitting patterns being emitted from positions a little deviated vertically as shown in FIG. 2, and any measurement error in depth to be reduced.

This is because in FIG. 20, the position of an emitting point Q of the light pattern is deviated in the perpendicular direction in the present embodiment, whereas in this case, it is at the same position, and therefore a straight line PQ becomes a line, and less errors occur than in the depth calculation using a straight line having different vertical positions.

Also, in this case, the entire surface of a liquid crystal barrier 532 [sic] is placed in a light transmitted state as shown in FIG. 24(d), whereby it can be utilized as a strobe for the camera for picking up a normal two-dimensional image.

Also, according to the fourth embodiment, in the main bodies of the shape measuring camera and object extracting camera, the depth image and color image are calculated, and recorded in the recording media. As shown in FIG. 31, in the main body of the camera, image data picked up in synchronism with the first and second strobes 505 and 506 in the light source is recorded in the recording media 504 through the media recording/reproducing part 538, and the image data is read out by an analysis device 39 configured by a personal computer or the like to obtain desired analysis result by the distance calculation part 535 and the color image calculation part 536. Thus, the

object may be extracted or the shape may be measured using the display part 532.

The image data can also be transferred to the analysis device 539 not through the recording media 504. For example, the camera body and the analysis device 539 are connected together using existing data communication means. In the wire communication, parallel data interface, serial data interface and telephone circuits can be used. In the radio communication, optical communication, infrared-ray communication, portable telephone network communication and radio wave communication can be used. Further, the analysis result can be recorded in the recording medium.

In this case, the image pickup part 533 is a moving image picking up video camera, and when the recording media 504 is a recording medium such as tape, it is normally utilized as a camera for picking up a color moving image. If the user lights a flash by pressing the push-button only when necessary and such an index signal as to allow only a video (such as a frame and a field) for the portion to be distinguished is stored in a recording medium in advance, the analysis device 539 is capable of extracting only an image for a portion having an index signal and calculating the color image and depth image only for the portion for outputting.

Also, in the fourth embodiment, the camera housing 501 has been provided with the light source part from the beginning, but it is conceivable to utilize a method to make only the light source part removable in such a manner that it is in a small-sized and easily-portable shape during normal color image picking up and that the light source part is mounted for use only during depth image picking up.

FIG. 37(a) shows an external light source having such a structure as an external strobe device for photography, mounted thereon with such a light source as shown in FIGS. 2 and 24. It is used by connecting it to the camera housing 501 as shown in FIG. 37(b) through a joint 549 with the camera. FIG. 38 shows an example for such a light source for eliminating any shadow of the object as shown in FIGS. 35 and 36.

In FIG. 38(a), light sources are symmetrically arranged on both sides of the joint 549. An aspect of the light sources connected to the camera is shown in FIG. 38(b). Also, in FIGS. 37 and 38, the camera body is connected to the light sources using such a structure as a strobe shoe for film cameras, and a method of mounting using a tripod mounting screw for cameras as shown in FIG. 39(a) is also conceivable.

In this case, it is configured such that a screw at the bottom of the camera housing 501 is used for mounting as shown in FIG. 39(b). If the light sources are separated as such a removable external light source device, the camera becomes large only during depth image picking up, and when used as a normal camera, it can conveniently become compact and lightweight.

Also, in the fifth embodiment, the user can denote a coordinate using the touch panel in the configuration of FIG. 31, and other means can be used. When for example, a personal computer is used, an input device such as a mouse or a keyboard can be used. In addition, a track ball, a switch, a volume and the like be can also utilized.

Also, in the fourth and fifth embodiments, the first and second strobes 505 and 506 in two light source parts are arranged at one side of the image pickup part 533 as shown in FIGS. 13, 21, 22 and 23, and in this case, when an object 540 and the background 541 are image-picked up in such an arrangement as shown in FIG. 32, light from the light sources is intercepted by the object 540 as shown in FIG. 33 to cause a shadow 542 in an image to be obtained.

This portion is an area where light from the light sources does not reach, and is an area where any information as a distance image cannot be obtained. In this case, light sources 543 and 544 having the same configuration

as the first and second strobes 505 and 506 in the light sources are arranged at a side opposite thereto with the lens as the center as shown in FIG. 34, whereby the area of this shadow can be eliminated. The method will be described below.

When the first and second strobes 505 and 506 in the light sources are used, an area β is a portion where any information as a distance image cannot be obtained, and when the light sources 543 and 544 are used, an area γ [sic] is a portion where any information as a distance image cannot be obtained. In the same manner as in the foregoing calculation, a distance image A and a color image A when the first and second strobes 505 and 506 in the light sources are used, and a distance image B and a color image B when the light sources 543 and 544 are used, are independently calculated respectively in advance. At this time, in the respective images, the portions in the areas β and γ [sic] are judged to be portions having low luminance from the image data obtained in advance.

Next, the distance images A and B are synthesized to newly generate a distance image free from any shadow area. This can be realized by adopting, if there exists an area which is not judged as the above-described portion having low luminance in either of the distance images A and B,

its value, and if neither of them is not the shadow area, by using an average value of both image data.

The same is applicable to a color image, and if at least either of the color images A and B has data for other than the shadow portion, it is possible to synthesize a new color image free from any shadow area.

In case of the foregoing configuration, it is necessary that light sources be arranged on the lateral sides or vertical sides of the lens. In this case, if the housing is configured such that housings 512 and 513 containing light source parts on the lateral sides of the camera body 511 are slid in opposite directions so as to be extended as shown in FIG. 35, the user can make it small-sized into the state shown in FIG. 35(a) for carrying during carrying, and extend it as shown in FIG. 35(b) to take the base length D large during the use, making it possible to prevent the depth image measuring accuracy from being degraded.

Also, the similar effect can be obtained even if the configuration is arranged such that the camera housing and the light sources can be folded into three stages as shown in FIG. 36. During carrying, they can be made small-sized by folding as shown in FIG. 36(a) for carrying, and during the use, the interval between the lens and the light sources, the base length D can be taken large by extending them as shown in FIG. 36(b).

Also, in order to arrange the lens and the light sources vertically as shown in FIG. 21(c), the housings 512 and 513 of FIG. 35 can be arranged on the vertical sides of the housing 11, and in FIG. 36, the housings 512 and 513 can be arranged on the vertical sides of the housing 51 [sic].

Industrial Applicability

As will be apparent from the foregoing description, according to a range finder device of the present invention, it is possible to provide, at low cost, a highly reliable range finder device capable of realizing all by electronic operations and not including any mechanical operations.

Also, according to a range finder device of the present invention, it is capable of measuring a distance with excellent accuracy even if light from the light source has a two-dimensional pattern.

Also, according to a range finder device of the present invention, it is capable of measuring a distance of an object in a place where light from the light source cannot be directly irradiated onto an object.

Further, according to a camera of the present invention as described above, a light source part having a simple configuration and high serviceability can be realized. Also, it has the effect that the depth image measuring accuracy is not degraded because the distance between the

camera lens and the light sources can be secured more than several tens centimeters during the use although it is small-sized during carrying. Also, the length and size of the object can be simply measured without touching, and the size of an object can be known from a color image once picked up. Also, it is possible to provide a shape measuring camera and an object extracting camera capable of simply extracting an object to be aimed at from an image photographed.